



# ***Solar Terrestrial Relations Observatory (STEREO) Pre-Phase-A Requirements Review***

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## **Software**

**Benjamin W. Ballard**

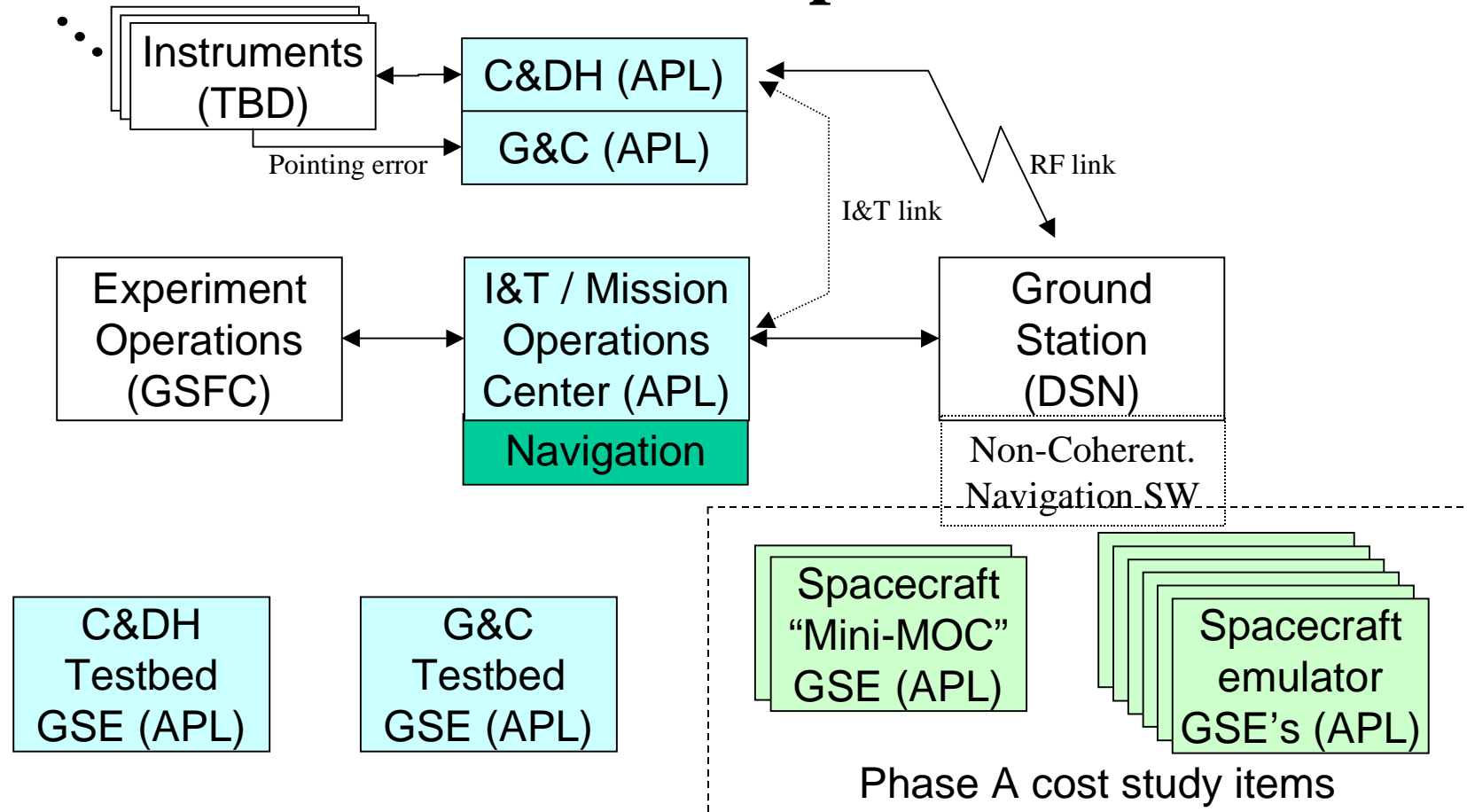
**The Johns Hopkins University  
Applied Physics Laboratory  
11100 Johns Hopkins Road  
Laurel, MD 20723-6099**



# Solar Terrestrial Relations Observatory (STEREO) Pre-Phase-A Requirements Review



## Software Components





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### **C&DH S/W Requirements**

- Support CCSDS-compatible uplink/downlink
- Perform power management
- Perform spacecraft health and status monitoring
- Maintain and distribute time to 0.1 sec accuracy
- Allow for software upgrade capability
- Distribute commands to subsystems
- Support 7.5 Gbit recorder w/simultaneous record, playback
  - Dump entire recorder in 8-hours at 200 kbits/sec., or...
  - Dump recorder at max. downlink rate of 800 kbits/sec...
  - While continuing to record new data from science instruments at their maximum rates



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### **C&DH S/W Requirements (con't)**

- Support science instruments
  - Provide “transparent” forwarding for instrument commands, telemetry
  - Provide limited space for instrument stored commands (~200 kbytes)
  - Label science and attitude history packets so they can be identified and routed to GSFC without inspection
  - Collect max rates (~450 kbps total) from all instruments simultaneously
  - Support “real-time” commanding and science downlink during ground contacts
- Support 500 bits/sec. “broadcast” telemetry mode
- No C&DH data compression is required



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## **C&DH Requirements vs. TIMED**

Feature	TIMED	STEREO	Software Impact
H/W redundant?	Yes	No	Requires new S/W loading approach
GPS?	Yes	No	Requires new timekeeping software
# Instruments	4	6-7	More 1553 remote terminals to manage
RS-422?	No	Yes	New driver needed; high speed I/O changes system scheduling and timing
Max science rate	55 kbps	450 kbps	Higher max. recording rate decreases flexibility in SSR management
Max downlink	4 Mbps	800 kbps	Lower max. downlink rate increases flexibility in SSR management
Broadcast?	No	Yes	New software needed to collect broadcast data, select between



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### **G&C S/W Requirements**

- Maintain spacecraft attitude safety
- Support spacecraft operational requirements
  - High gain antenna pointing
  - Solar panel alignment
  - Autonomous momentum management
- Support instrument requirements
  - Maintain solar pointing within long term and jitter specifications
  - Provide Sun keep-in violation, momentum dump warnings
- Generate G&C system telemetry
  - Attitude history
  - Anomalous event dumps
  - Routine G&C status and health reports



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## **G&C Requirements vs. TIMED**

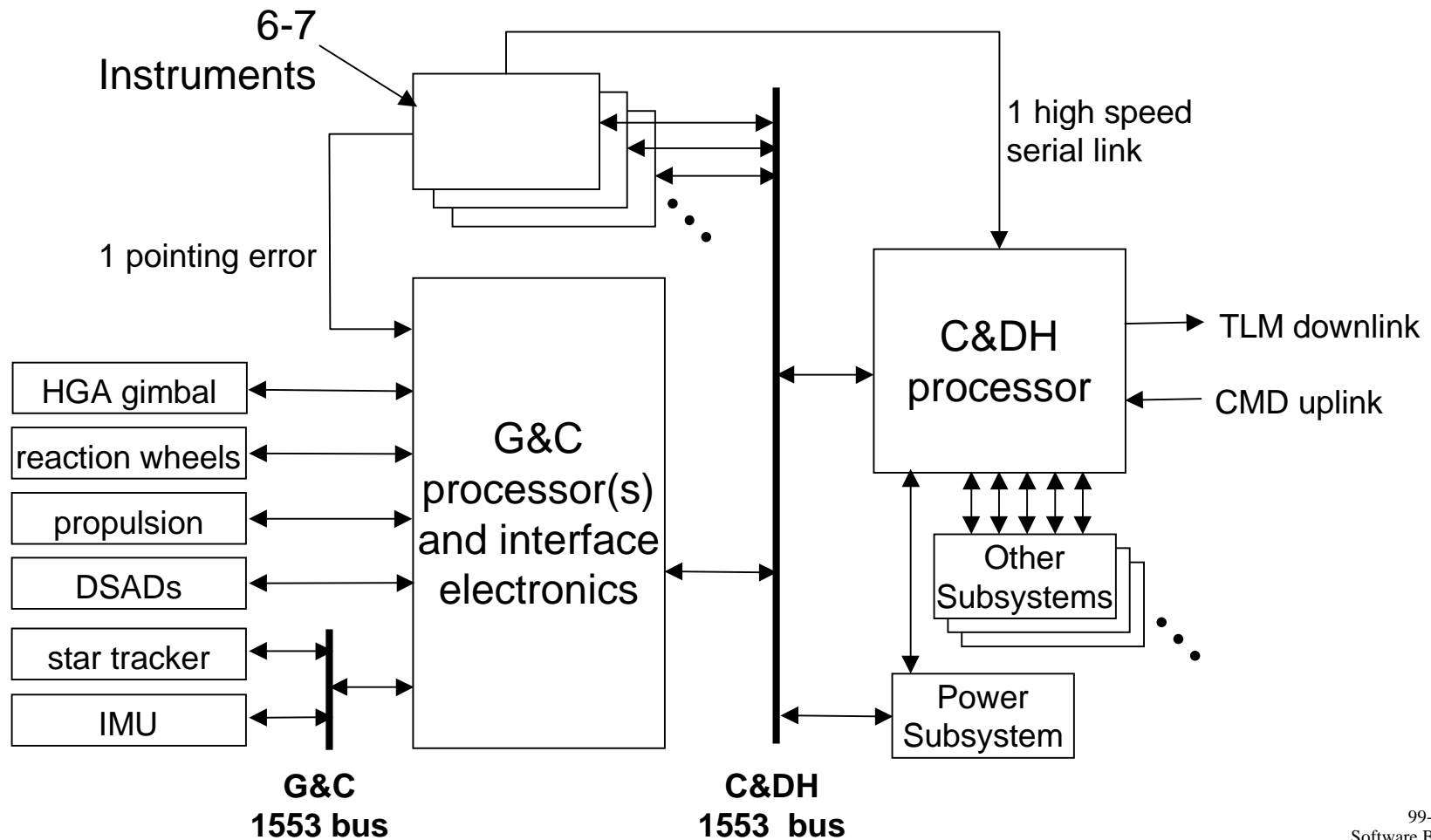
Feature	TIMED	STEREO	Software Impact
H/W redundant?	Yes	No	Requires new S/W loading approach
GPS?	Yes	No	Requires new orbit determination software
Momentum management	Torque rods	Cold gas	Requires new I/O and control software
Star tracker, IMU, etc.	Known	TBD	Requires new I/O and control software if devices differ from TIMED
High gain antenna	No	Yes	Requires new I/O and control software for gimbal
Error signal	No	Yes	Requires new I/O and control software
Control update frequency	10 Hz	TBD	Unknown until further analysis; could help or hurt processor margins



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## Flight Software Environment







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# **C&DH Software Baseline**

- TIMED architecture
  - Reuse requirements document as starting point
  - 12 MHz Mongoose running Nucleus+ RTOS
  - Same approach to uplink, downlink, 1553 bus management
  - Add drivers for RS-422 high speed link
  - Delete instrument daily packet quota enforcement
  - Power management requirements TBD
- Load estimates
  - CPU usage: 25% (based on TIMED estimates updated for STEREO)
  - Memory: TIMED is under 30% usage of code space (RAM and flash), assuming 50% of memory is available for code



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## **G&C Software Baseline**

- TIMED software architecture
  - 12 MHz Mongoose running Nucleus+ RTOS, with RTX2010 based Attitude Interface Electronics
  - Reuse requirements documents as starting point
  - Eliminate attitude processing in AIE to reduce complexity and regain processor and memory margin
  - Use RTW again to automatically generate attitude “c” code for GCC
- Load estimates
  - CPU usage: AIU usage about 25%; GCC unmeasured
  - Memory: TIMED AIU uses over 85% of RAM; GCC uses <30% of RAM allocated for code



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### **I&T S/W Requirements**

- Deliver commands to S/C and instruments at bench system
- Assess and archive spacecraft telemetry
- Deliver instrument telemetry to instrument teams
- Provide visibility into internal spacecraft interfaces for test purposes
- Support multiple hardware configurations as integration proceeds
- Support test scripting, data collection, and problem reporting and resolution



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# **Mission Operations S/W Requirements**

- Deliver and log commands for two spacecraft and their instruments
- Receive and distribute all downlink telemetry
- Monitor spacecraft health and safety
- Assess and archive spacecraft telemetry data
- Produce and distribute time correlation and navigation data
- Maintain spacecraft command and telemetry dictionaries
- Support spacecraft activity planning
- Maintain configuration control of uploadable software and parameters



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### **Mission Operations Requirements vs. TIMED**

Feature	TIMED	STEREO	Software Impact
# spacecraft	1	2	Requires separate command and telemetry databases, sorting commands and telemetry by spacecraft, and supporting 2 passes simultaneously
Ground station	APL/ LEO-T	DSN	Requires changes to contact planning
GPS?	Yes	No	Requires ground-based navigation team with interfaces to DSN
Unsupported passes	Goal	Weekend	Requires up-front commitment to more automated operations



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## **GSE Software**

- **G&C testbed**
  - Connects to G&C computer; accessible via Ethernet
  - Simulates G&C system components and environment
  - Allows real time closed loop tests of the attitude system
  - Becomes part of the real time spacecraft simulator after launch
- **C&DH testbed**
  - Connects to C&DH computer; accessible via Ethernet
  - Simulates C&DH interfaces and environment
  - Allows real time tests of C&DH hardware and software



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### **GSE Software (con't)**

- Mini-MOC (if implemented)
  - Is a stripped-down version of the MOC, available early in the program, for use in G&C and C&DH subsystem testing.
  - Can command and receive telemetry from both the subsystem under test and supporting GSE
  - Uses the same command and telemetry dictionaries, command procedures, and display pages as the MOC
- Spacecraft emulator (if implemented)
  - Accessible via Ethernet
  - Connects to instruments via their spacecraft interfaces (1553, serial)
  - Emulates spacecraft functions that support instruments
  - Allows instrument checkout before spacecraft integration
  - TIMED provided one emulator to each instrument developer



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### **Trade Studies for Phase A/B**

- Elimination of the processor in the AIE
  - G&C computer would manage all attitude tasks
  - Trade study must ensure the G&C computer would not be overloaded
  - TIMED AIE boot and application software were costly
  - AIE's RTX 2010 development tools are no longer supported
- Selective SSR playback to allow direct replay of missed transfer frames without playing back a whole segment
- Use of variable length packets
  - Study whether benefits of variable length packets outweigh costs





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### **Trade Studies for Phase A/B (con't)**

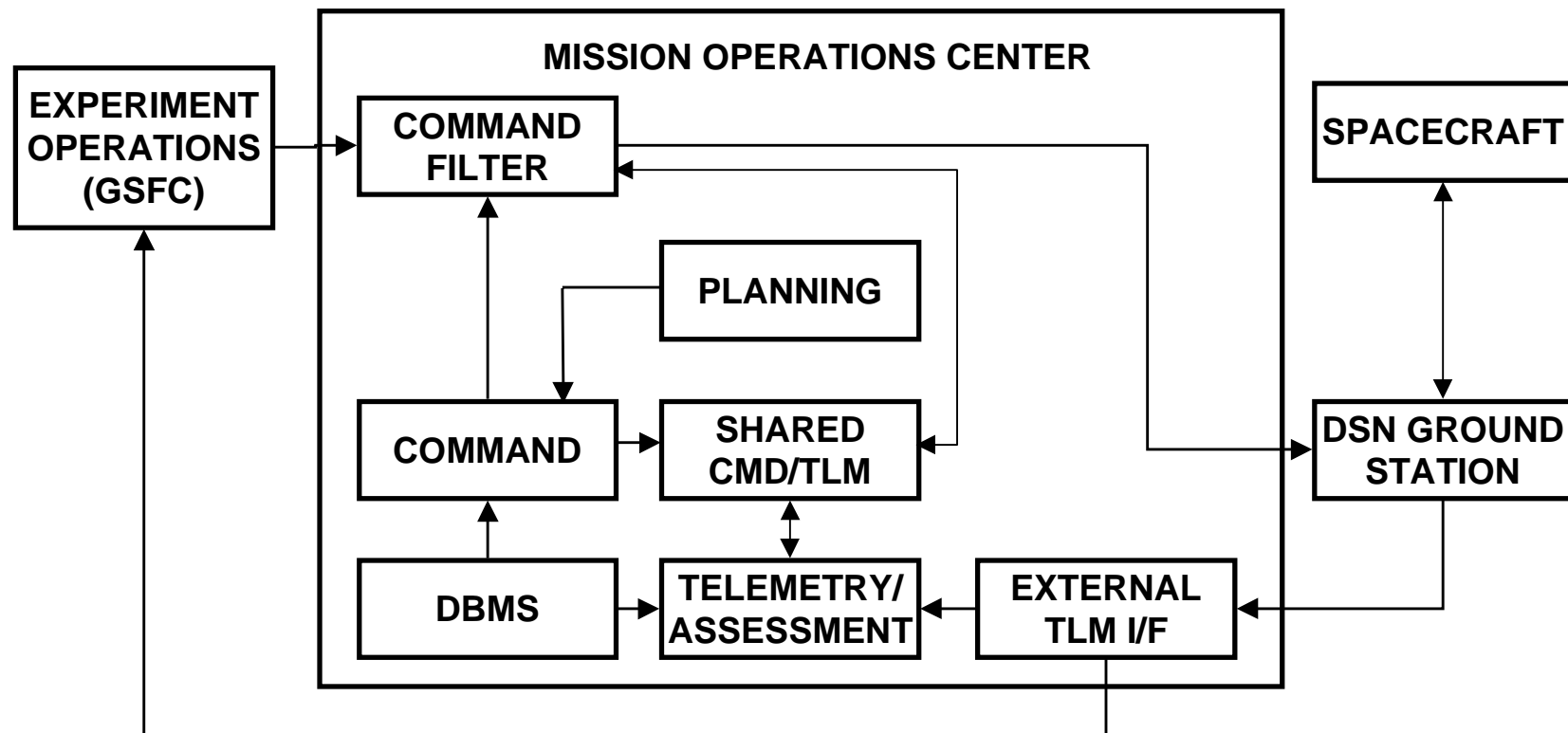
- Operating systems, tools
  - Nucleus+ (TIMED RTOS for Mongoose), VxWorks, VRTX
  - TASKING (TIMED development tools for Mongoose), gnu
- Use of EPOCH for Mission Operations Center
- Implementation of Mini-MOC, spacecraft emulator
  - Cost/benefit tradeoff



# *Solar Terrestrial Relations Observatory (STEREO) Pre-Phase-A Requirements Review*



## **Mission Operations S/W Baseline (Based on TIMED EPOCH 2000 System)**





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# **Technology Insertion Candidates**

- Use of commercially available file system extensions to Real Time Operating System
  - Code and parameter upload and download operations become simple file transfers
  - Easy, familiar model for Mission Operations
- Non-coherent Doppler navigation (with JHU/APL-supplied hardware and software at DSN ground stations)
- Unattended weekend operations